

# CERTIFICATE OF ANALYSIS

## 11X AR5 (batch K)

### Certified Reference Material Information

Type: ABRASION-RESISTANT CAST IRON (CHILL CAST)

Form and Size: Disc ~40mm diameter

Manufactured by: Polycast Ltd

Certified and Supplied by: MBH Analytical Ltd

### Assigned Values

#### Percentage element by weight

Element	C	Si	Mn	P	S	Cr	Mo	Ni
Value <sup>1</sup>	3.20	1.695	0.535	0.0405	0.0215	8.83	0.149	5.15
Uncertainty <sup>2</sup>	0.02	0.015	0.008	0.0010	0.0009	0.05	0.003	0.04

Element	Al	Cu	Nb	Ti	V	Co	W	Pb
Value <sup>1</sup>	0.120	0.0517	0.027	0.062	0.0533	0.34	0.073	0.0035
Uncertainty <sup>2</sup>	0.002	0.0008	0.002	0.002	0.0016	0.02	0.003	0.0003

### Definitions

- <sup>1</sup> The certified values are the present best estimates of the true content for each element. Each value is a panel consensus, based on the averaged results of an interlaboratory testing programme, detailed on page 3.
- <sup>2</sup> The uncertainty values are generated from the 95% confidence interval derived from the wet analysis results, in combination with a statistical assessment of the homogeneity data, as described on page 2.

### Certified by:

MBH ANALYTICAL LIMITED \_\_\_\_\_

on 20<sup>th</sup> April 2016

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## **Method of Preparation**

This reference material was produced from commercial-purity metals, and master alloys. The discs are the product of one melt poured into multiple chill moulds with feeding systems designed to ensure sound discs. Approximately 2mm has been removed from the cast faces of the discs to minimise surface effects.

## **Sampling**

Milled samples for chemical analysis were taken from the working faces of several discs. In addition, at least 10% of all discs were selected randomly from throughout the casting process, for non-destructive homogeneity checking.

## **Homogeneity**

Samples representative of the batch were checked for uniformity using an optical emission spectrometer. Using the combined data from each surface, standard deviation values were derived for each element.

These values were combined with the 95% half-width confidence intervals ( $C_{(95\%)}$ ) obtained from the wet analysis programme, using the square-root of the summed squares, to derive the final uncertainty values.

## **Chemical Analysis**

Analysis was carried out on millings taken from samples representative of the product. It was performed by a panel of laboratories mostly operating within the terms of EN ISO/IEC 17025 - 2005, using documented standard reference methods and validated by appropriate reference materials.

The individual values listed overpage are the average of each analyst's results.

## **Traceability**

Much of the analytical work performed to assess this material has been carried out by laboratories with proven competence, as indicated by their accreditation to ISO 17025. It is an implicit requirement for this accreditation that analytical work should be performed with due traceability, via an unbroken chain of comparisons, each with stated uncertainty, to primary standards such as the mole, or to nationally- or internationally-recognised reference materials. In addition, some of the results derived as part of this testing programme have traceability to NIST standards, as part of the analytical calibration or process control.

## **Usage**

Intended use: With optical emission and X-ray fluorescence spectrometers.

Recommended method of use: Cast irons are generally prepared by finishing, milling, turning or polishing. However, users are recommended to follow the calibration and sample preparation procedures specified by the relevant instrument manufacturer.

Preparation should be the same for reference materials and the samples for test.

A minimum of four consistent replicate analyses is recommended to optimise precision and accuracy. Users are advised to check against possible bias between reference materials and production samples due to differences in metallurgical history, and be aware of possible inter-element effects.

## Analytical Data

### Percentage element by weight

Sample	C	Si	Mn	P	S	Cr	Mo	Ni
1	3.171	1.669	0.520	0.0395	0.0199	8.715	0.1436	5.076
2	3.180	1.673	0.521	0.0400	0.0203	8.765	0.1447	5.090
3	3.184	1.675	0.523	0.0400	0.0205	8.775	0.1450	5.092
4	3.186	1.676	0.524	0.0406	0.0205	8.791	0.1456	5.101
5	3.190	1.685	0.527	0.0406	0.0209	8.811	0.1461	5.104
6	3.201	1.688	0.529	0.0408	0.0212	8.823	0.1465	5.116
7	3.201	1.694	0.534	0.0408	0.0214	8.846	0.1475	5.123
8	3.210	1.703	0.540	0.0409	0.0214	8.848	0.1500	5.169
9	3.213	1.706	0.545	0.0410	0.0219	8.869	0.1509	5.175
10	3.220	1.720	0.545		0.0220	8.900	0.1518	5.185
11	3.224	1.721	0.548		0.0221	8.903	0.1530	5.205
12	3.230	1.731	0.549		0.0221	8.955	0.1540	5.205
13			0.555		0.0225		0.1540	5.207
14					0.0226			5.216
15					0.0227			5.217
<b>Mean</b>	<b>3.201</b>	<b>1.695</b>	<b>0.535</b>	<b>0.0405</b>	<b>0.0215</b>	<b>8.834</b>	<b>0.1487</b>	<b>5.152</b>
<b>Std Dev</b>	0.019	0.021	0.012	0.0005	0.0009	0.068	0.0038	0.053
<b>C<sub>(95%)</sub></b>	0.012	0.013	0.007	0.0004	0.0005	0.043	0.0023	0.029

Sample	Al	Cu	Nb	Ti	V	Co	W	Pb
1	0.1190	0.0504	0.0243	0.0599	0.0494	0.327	0.0701	0.0031
2	0.1193	0.0504	0.0250	0.0599	0.0500	0.328	0.0709	0.0033
3	0.1195	0.0505	0.0252	0.0600	0.0505	0.329	0.0712	0.0034
4	0.1200	0.0508	0.0252	0.0604	0.0510	0.329	0.0721	0.0035
5	0.1200	0.0511	0.0256	0.0612	0.0512	0.329	0.0721	0.0035
6	0.1205	0.0514	0.0256	0.0614	0.0515	0.330	0.0725	0.0037
7	0.1206	0.0516	0.0263	0.0616	0.0534	0.342	0.0740	0.0041
8	0.1208	0.0516	0.0282	0.0621	0.0544	0.345	0.0741	
9	0.1215	0.0517	0.0293	0.0630	0.0547	0.346	0.0745	
10	0.1230	0.0520	0.0294	0.0632	0.0547	0.350	0.0745	
11		0.0520	0.0298	0.0633	0.0548	0.351	0.0747	
12		0.0533	0.0302	0.0634	0.0553	0.353		
13		0.0534			0.0556	0.354		
14		0.0536			0.0556	0.355		
15					0.0568	0.356		
<b>Mean</b>	<b>0.1204</b>	<b>0.0517</b>	<b>0.0270</b>	<b>0.0616</b>	<b>0.0533</b>	<b>0.342</b>	<b>0.0728</b>	<b>0.0035</b>
<b>Std Dev</b>	0.0012	0.0011	0.0022	0.0014	0.0024	0.012	0.0016	0.0003
<b>C<sub>(95%)</sub></b>	0.0008	0.0006	0.0014	0.0009	0.0013	0.006	0.0011	0.0003

Note:  $C_{(95\%)}$  is the 95% half-width confidence interval derived from the equation:

$$C_{(95\%)} = (t \times SD) / \sqrt{n}$$

where n is the number of available values, t is the Student's t value for n-1 degrees of freedom, and SD is the standard deviation of the test results.

## Participating Laboratories

Exova Ltd	Middlesbrough, England	UKAS accreditation 0239
Sheffield Assay Office	Sheffield, England	UKAS accreditation 0012
Metals Technology (Testing) Ltd	Sheffield, England	UKAS accreditation 0963
Universal Scientific Laboratory Pty Ltd	Milperra, NSW, Australia	NATA accreditation 0492
Laboratory Testing, Inc	Hatfield, PA, USA	A2LA accreditation 0117
Shanghai Jinyi Test Technology Co	Shanghai, China	CNAL accreditation 0783
Shandong Metallurgical & Science Research	Jinan, Shandong, China	CNAS accreditation 1461
Raghavendra Spectromet Laboratory	Bangalore, India	NABL accreditation 0371
Bureau Veritas CPS Pvt	Chennai, India	NABL accreditation 0025
TCR Engineering Services Ltd	Mumbai, India	NABL accreditation 0367
Tec-Eurolab	Campogalliano, Italy	ACCREDIA accreditation 52
Instytut Metalurgii Zelaza	Gliwice, Poland	PCA accreditation AB554
Mineral & Metallurgical Laboratories	Bangalore, India	
Coleshill Laboratories Ltd	Birmingham, England	
AMG Superalloys UK Ltd	Rotherham, England	
Analyticka Laborator Lithea, sro	Brno, Czech Republic	

Note: to achieve the above accreditation (UKAS, NATA, etc), test houses are required to demonstrate conformity to the general requirements of EN ISO/IEC 17025.

## Analytical Methods Used

ELEMENT	RESULT No. & METHOD		
	ICP-AES	FAAS	OTHER
Carbon	-	-	all combustion (volumetric or IR detection)
Silicon	2, 6-8	-	1, 9, 10 photometric (molybdenum blue)
Manganese	2, 5-8, 11, 12	1, 3	3-5, 11, 12 gravimetric (perchloric acid)
Phosphorus	2, 5, 8, 9	-	4, 13 volumetric (arsenite, FAS)
Sulfur	5	-	9, 10 photometric (periodate)
Chromium	2-4, 8	1	1, 6, 7 volumetric (alkalimetric)
Molybdenum	1, 2, 5, 7, 9, 10, 12, 13	4, 6, 8	3, 4 photometric (molybdenum blue)
Nickel	1, 3, 5, 7-9, 12-13	6	1-4, 6-15 combustion (volumetric or IR detection)
Aluminium	2, 3, 6-8	4, 5, 9	5-7, 9, 10, 12 volumetric (ferrous ammonium sulfate)
Copper	2-6, 10, 11, 13, 14	7, 12	11 photometric (diphenyl carbazide)
Niobium	1-10	11	3, 11 photometric (thiocyanate)
Titanium	2, 4, 7, 10-12	3, 6, 8	2, 10, 14, 15 gravimetric (dimethyl glyoxime)
Vanadium	1, 3, 4, 7-11, 13, 14	2, 6, 15	4, 11 photometric (dimethyl glyoxime)
Cobalt	1, 2, 6, 7, 9-11, 13-15	3-5	1 photometric (chrome azurol s)
Tungsten	1, 2, 4-6, 8-10	11	10 volumetric (EDTA)
Lead	1-5, 7	6	1, 8 photometric (BCO)
			9 volumetric (thiosulfate)
			12 photometric (chlorosulfophenol)
			1, 9 photometric (diantipyryl methane)
			5 photometric (hydrogen peroxide)
			5, 12 volumetric (ferrous ammonium sulfate)
			8 photometric (2 $\beta$ -naphthol)
			12 gravimetric (oxide)
			7 photometric (thiocyanate)
			3 gravimetric

## Notes

This Certified Reference Material has been produced and certified in accordance with the requirements of ISO Guide 34-2009, ISO Guide 31-2015 and ISO Guide 35-2006, taking into account the requirements of the ISO Guide to the Expression of Uncertainty in Measurement (GUM).

The unidirectional solidification effects associated with this method of chill casting, have led to the formation of inhomogeneous segregates in the rear portion of the disc. The above certification is therefore only applicable from the front face of the disc. Material to the rear of the disc, to a depth of ~5mm, is not certified.

This material will remain stable provided adequate precautions are taken to protect it from cross-contamination, extremes of temperature and atmospheric moisture. All production records will be retained for a period of 20 years from the date of this certificate. Technical support for this certification will therefore expire in April 2036, although we reserve the right to make changes as issue revisions, in the intervening period.

The manufacture, analysis and certification of this product were supervised by L Maxim, Technical Director, MBH Analytical Ltd.

The material to which this certificate of analysis refers is supplied subject to our general conditions of sale.